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Extensions to RSVP-TE for Label Switched Path (LSP) Egress Protection

Abstract

This document describes extensions to Resource Reservation Protocol - Traffic Engineering (RSVP-TE) for locally protecting the egress node(s) of a Point-to-Point (P2P) or Point-to-Multipoint (P2MP) Traffic Engineered (TE) Label Switched Path (LSP).

Status of This Memo

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1. Introduction

[RFC4090] describes two methods for locally protecting the transit nodes of a P2P LSP: one-to-one and facility protection. [RFC4875] specifies how these methods can be used to protect the transit nodes of a P2MP LSP. These documents do not discuss the procedures for locally protecting the egress node(s) of an LSP.

This document fills that void and specifies extensions to RSVP-TE for local protection of the egress node(s) of an LSP. "Egress node" and "egress" are used interchangeably.

1.1. Local Protection of Egress Nodes

In general, locally protecting an egress node of an LSP means that when the egress node fails, the traffic that the LSP carries will be delivered to its destination by the direct upstream node of the egress node to a backup egress node. Without protecting the egress node of the LSP, when the egress node fails, the traffic will be lost (i.e., the traffic will not be delivered to its destination).

Figure 1 shows an example of using backup LSPs to locally protect egress nodes L1 and L2 of a primary P2MP LSP starting from ingress node R1. La and Lb are the designated backup egress nodes for primary egress nodes L1 and L2, respectively. The backup LSP for protecting L1 is from its upstream node R3 to backup egress node La, and the backup LSP for protecting L2 is from R5 to Lb.

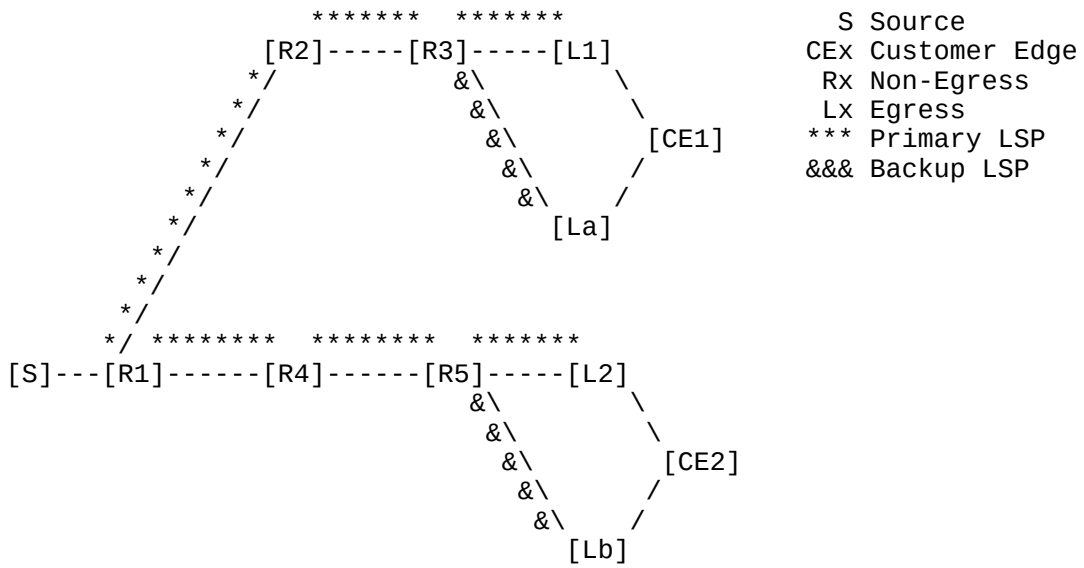


Figure 1: Backup LSP for Locally Protecting Egress

During normal operations, the traffic carried by the P2MP LSP is sent through R3 to L1, which delivers the traffic to its destination CE1. When R3 detects the failure of L1, R3 switches the traffic to the backup LSP to backup egress node La, which delivers the traffic to CE1. The time for switching the traffic is within tens of milliseconds.

The exact mechanism by which the failure of the primary egress node is detected by the upstream node R3 is out of the scope of this document.

In the beginning, the primary P2MP LSP from ingress node R1 to primary egress nodes L1 and L2 is configured. It may be used to transport the traffic from source S, which is connected to R1, to destinations CE1 and CE2, which are connected to L1 and L2, respectively.

To protect the primary egress nodes L1 and L2, one configures on the ingress node R1 a backup egress node for L1, another backup egress node for L2, and other options. After the configuration, the ingress node sends a Path message for the LSP with information such as the Secondary Explicit Route Objects (SEROs), refer to Section 4.1, containing the backup egress nodes for protecting the primary egress nodes.

After receiving the Path message with the information, the upstream node of a primary egress node sets up a backup LSP to the corresponding backup egress node for protecting the primary egress node.

2. Conventions Used in This Document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Terminology

The following terminology is used in this document.

LSP: Label Switched Path

TE: Traffic Engineering

P2MP: Point-to-Multipoint

P2P: Point-to-Point

LSR: Label Switching Router

RSVP: Resource Reservation Protocol

S2L: Source-to-Leaf

SERO: Secondary Explicit Route Object

RRO: Record Route Object

BFD: Bidirectional Forwarding Detection

VPN: Virtual Private Network

L3VPN: Layer 3 VPN

VRF: Virtual Routing and Forwarding

LFIB: Label Forwarding Information Base

UA: Upstream Assigned

PLR: Point of Local Repair

BGP: Border Gateway Protocol

CE: Customer Edge

PE: Provider Edge

4. Protocol Extensions

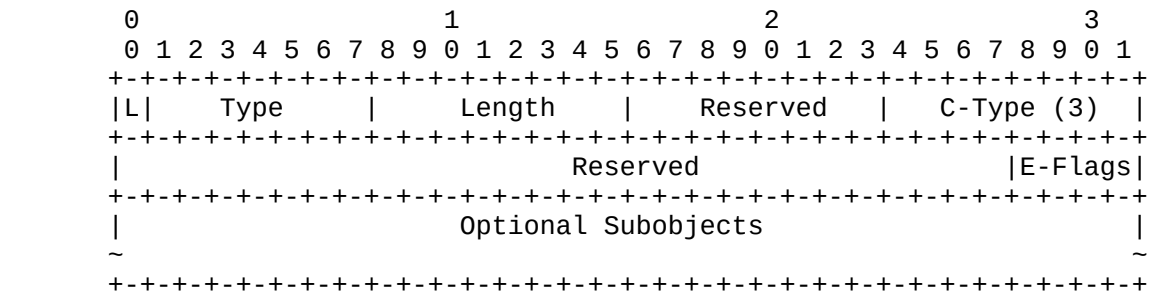
4.1. Extensions to SERO

The Secondary Explicit Route Object (SERO) is defined in [RFC4873]. The format of the SERO is reused.

The SERO used for protecting a primary egress node of a primary LSP may be added into the Path messages for the LSP and sent from the ingress node of the LSP to the upstream node of the egress node. It contains three subobjects.

The first subobject (refer to Section 4.2 of [RFC4873]) indicates the branch node that is to originate the backup LSP (to a backup egress node). The branch node is typically the direct upstream node of the primary egress node of the primary LSP. If the direct upstream node does not support local protection against the failure of the primary egress node, the branch node can be any (upstream) node on the primary LSP. In this case, the backup LSP from the branch node to the backup egress node protects against failures on the segment of the primary LSP from the branch node to, and including, the primary egress node.

The second subobject is an Egress Protection subobject, which is a PROTECTION object with a new C-Type (3). The format of the Egress Protection subobject is defined as follows:



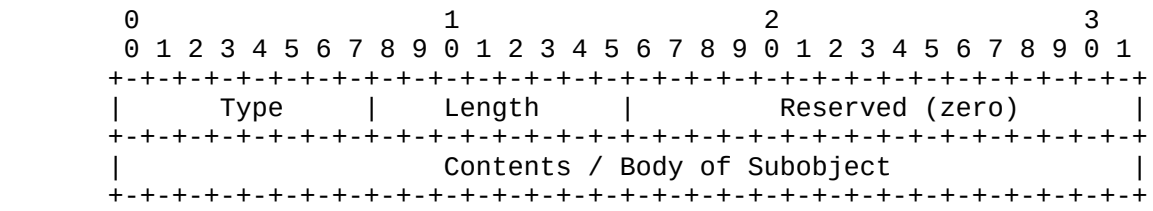
E-Flags are defined for local protection of egress nodes.

Bit 31 ("egress local protection" flag): It is the least significant bit of the 32-bit word and is set to 1, which indicates that local protection of egress nodes is desired.

Bit 30 ("S2L sub-LSP backup desired" flag): It is the second least significant bit of the 32-bit word and is set to 1, which indicates an S2L sub-LSP (refer to [RFC4875]) is desired for protecting an egress node of a P2MP LSP.

The Reserved parts MUST be set to zero on transmission and MUST be ignored on receipt.

Four optional subobjects are defined: they are IPv4 and IPv6 primary egress node subobjects as well as IPv4 and IPv6 P2P LSP ID subobjects. IPv4 and IPv6 primary egress node subobjects indicate the IPv4 and IPv6 address of the primary egress node, respectively. IPv4 and IPv6 P2P LSP ID subobjects contain the information for identifying IPv4 and IPv6 backup P2P LSP tunnels, respectively. Their contents are described in Sections 4.1.1 through 4.1.2.2. They have the following format:



where Type is the type of a subobject and Length is the total size of the subobject in bytes, including Type, Length, and Contents fields. The Reserved field MUST be set to zero on transmission and MUST be ignored on receipt.

The third (final) subobject (refer to Section 4.2 of [RFC4873]) in the SERO contains the egress node of the backup LSP, i.e., the address of the backup egress node in the place of the merge node.

After the upstream node of the primary egress node (a.k.a. the branch node) receives the SERO and determines a backup egress node for the primary egress node, it computes a path from itself to the backup egress node and sets up a backup LSP along the path for protecting the primary egress node according to the information in the FAST_REROUTE object in the Path message. For example, if facility protection is desired, it is provided for the primary egress node.

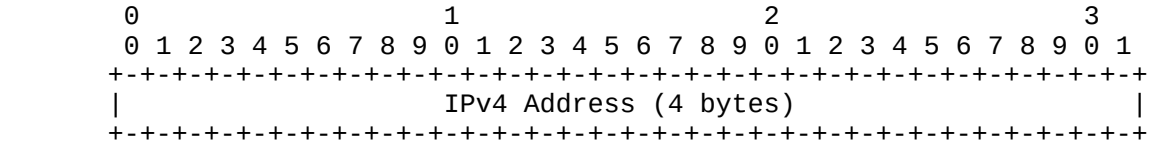
The upstream node constructs a new SERO based on the SERO received and adds the new SERO into the Path message for the backup LSP. The new SERO also contains three subobjects as the SERO for the primary LSP. The first subobject in the new SERO indicates the upstream node, which may be copied from the first subobject in the SERO received. The second subobject in the new SERO includes a primary egress node, which indicates the address of the primary egress node. The third one contains the backup egress node.

The upstream node updates the SERO in the Path message for the primary LSP. The Egress Protection subobject in the SERO contains a subobject called a P2P LSP ID subobject, which contains the information for identifying the backup LSP. The final subobject in the SERO indicates the address of the backup egress node.

4.1.1. Primary Egress Subobject

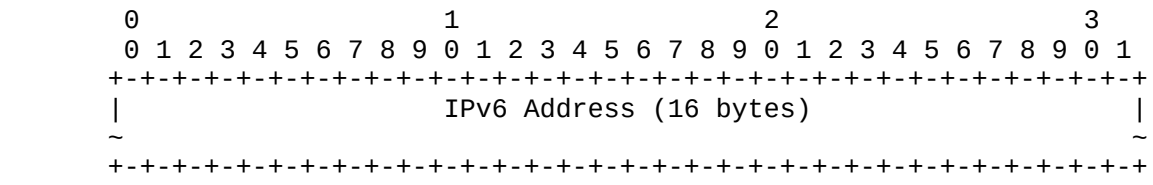
There are two primary egress subobjects: the IPv4 primary egress subobject and the IPv6 primary egress subobject.

The Type of an IPv4 primary egress subobject is 1, and the body of the subobject is given below:



- IPv4 Address: The IPv4 address of the primary egress node.

The Type of an IPv6 primary egress subobject is 2, and the body of the subobject is shown below:



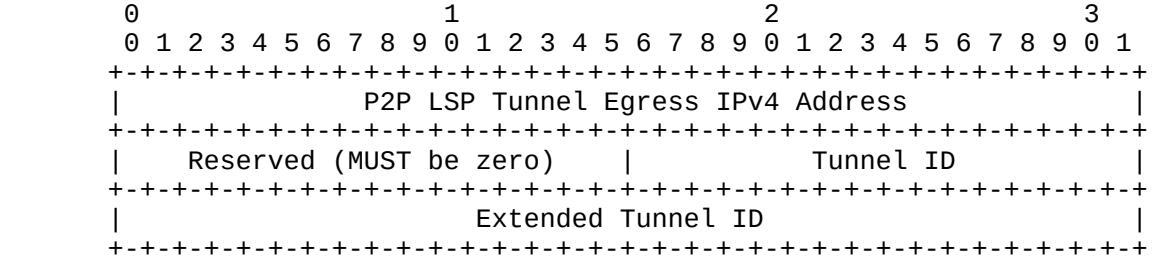
- IPv6 Address: The IPv6 address of the primary egress node.

4.1.2. P2P LSP ID Subobject

A P2P LSP ID subobject contains the information for identifying a backup P2P LSP tunnel.

4.1.2.1. IPv4 P2P LSP ID Subobject

The Type of an IPv4 P2P LSP ID subobject is 3, and the body of the subobject is shown below:



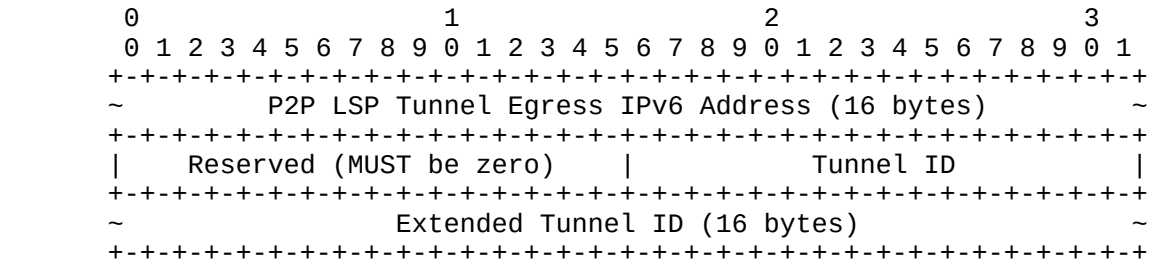
- P2P LSP Tunnel Egress IPv4 Address: The IPv4 address of the egress node of the tunnel.

- Tunnel ID (refer to [RFC4875] and [RFC3209]): A 16-bit identifier that remains constant over the life of the tunnel and occupies the least significant 16 bits of the 32-bit word.

- Extended Tunnel ID (refer to [RFC4875] and [RFC3209]): A 4-byte identifier that remains constant over the life of the tunnel.

4.1.2.2. IPv6 P2P LSP ID Subobject

The Type of an IPv6 P2P LSP ID subobject is 4, and the body of the subobject is illustrated below:



- P2P LSP Tunnel Egress IPv6 Address: The IPv6 address of the egress node of the tunnel.

- Tunnel ID (refer to [RFC4875] and [RFC3209]): A 16-bit identifier that remains constant over the life of the tunnel and occupies the least significant 16 bits of the 32-bit word.

- Extended Tunnel ID (refer to [RFC4875] and [RFC3209]): A 16-byte identifier that remains constant over the life of the tunnel.

5. Egress Protection Behaviors

5.1. Ingress Behavior

To protect a primary egress node of an LSP, the ingress node MUST set the "label recording desired" flag and the "node protection desired" flag in the SESSION_ATTRIBUTE object.

If one-to-one backup or facility backup is desired to protect a primary egress node of an LSP, the ingress node MUST include a FAST_REROUTE object and set the "one-to-one backup desired" or "facility backup desired" flag, respectively.

If S2L sub-LSP backup is desired to protect a primary egress node of a P2MP LSP, the ingress node MUST set the "S2L sub-LSP backup desired" flag in an SERO object.

The decision to instantiate a backup egress node for protecting the primary egress node of an LSP can be initiated by either the ingress node or the primary egress node of that LSP, but not both.

A backup egress node MUST be configured on the ingress node of an LSP to protect a primary egress node of the LSP if and only if the backup egress node is not configured on the primary egress node (refer to Section 5.2).

The ingress node MUST send a Path message for the LSP with the objects above and the SEROs for protecting egress nodes of the LSP if protection of the egress nodes is desired. For each primary egress node of the LSP to be protected, the ingress node MUST add an SERO object into the Path message if the backup egress node, or some options, are given. If the backup egress node is given, then the final subobject in the SERO contains it; otherwise, the address in the final subobject is zero.

5.2. Primary Egress Behavior

To protect a primary egress node of an LSP, a backup egress node MUST be configured on the primary egress node of the LSP to protect the primary egress node if and only if the backup egress node is not configured on the ingress node of the LSP (refer to Section 5.1).

If the backup egress node is configured on the primary egress node of the LSP, the primary egress node MUST send its upstream node a Resv message for the LSP with an SERO for protecting the primary egress node. It sets the flags in the SERO in the same way as an ingress node.

If the LSP carries the service traffic with a service label, the primary egress node sends its corresponding backup egress node the information about the service label as a UA label (refer to [RFC5331]) and the related forwarding.

5.3. Backup Egress Behavior

When a backup egress node receives a Path message for an LSP, it determines whether the LSP is used for egress local protection by checking the SERO with an Egress Protection subobject in the message. If there is an Egress Protection subobject in the Path message for the LSP and the "egress local protection" flag in the object is set to 1, the LSP is the backup LSP for local protection of an egress node. The primary egress node to be protected is in the primary egress subobject in the SERO.

When the backup egress node receives the information about a UA label and its related forwarding from the primary egress node, it uses the backup LSP label as a context label and creates a forwarding entry using the information about the UA label and the related forwarding.

This forwarding entry is in a forwarding table for the primary egress node.

When the primary egress node fails, its upstream node switches the traffic from the primary LSP to the backup LSP to the backup egress node, which delivers the traffic to its receiver, such as a CE, using the backup LSP label as a context label to get the forwarding table for the primary egress node and using the service label as a UA label to find the forwarding entry in the table to forward the traffic to the receiver.

5.4. Transit Node and PLR Behavior

If a transit node of an LSP receives the Path message with the SEROs and it is not an upstream node of any primary egress node of the LSP as a branch node, it MUST forward them unchanged.

If the transit node is the upstream node of a primary egress node to be protected as a branch node, it determines the backup egress node, obtains a path for the backup LSP, and sets up the backup LSP along the path. If the upstream node receives the Resv message with an SERO object, it MUST send its upstream node the Resv message without the object.

The PLR (which is the upstream node of the primary egress node a.k.a. the branch node) MUST extract the backup egress node from the respective SERO object in either a Path or a Resv message. If no matching SERO object is found, the PLR tries to find the backup egress node, which is not the primary egress node but has the same IP address as the destination IP address of the LSP.

Note that if a backup egress node is not configured explicitly for protecting a primary egress node, the primary egress node and the backup egress node SHOULD have the same local address configured, and the cost to the local address on the backup egress node SHOULD be much bigger than the cost to the local address on the primary egress node. Thus, the primary egress node and backup egress node are considered as a "virtual node". Note that the backup egress node is different from this local address (e.g., from the primary egress node’s point of view). In other words, it is identified by an address different from this local address.

After obtaining the backup egress node, the PLR computes a backup path from itself to the backup egress node and sets up a backup LSP along the path. It excludes the segment including the primary egress node to be protected when computing the path. The PLR sends the primary egress node a Path message with an SERO for the primary LSP,

which indicates the backup egress node by the final subobject in the SERO. The PLR puts an SERO into the Path messages for the backup LSP, which indicates the primary egress node.

The PLR MUST provide one-to-one backup protection for the primary egress node if the "one-to-one backup desired" flag is set in the message; otherwise, it MUST provide facility backup protection if the "facility backup desired" flag is set.

The PLR MUST set the protection flags in the RRO subobject for the primary egress node in the Resv message according to the status of the primary egress node and the backup LSP protecting the primary egress node. For example, it sets the "local protection available" flag and the "node protection" flag, which indicate that the primary egress node is protected when the backup LSP is up and ready to protect the primary egress node.

5.4.1. Signaling for One-to-One Protection

The behavior of the upstream node of a primary egress node of an LSP (as a PLR) is the same as that of a PLR for one-to-one backup described in [RFC4090], except that the upstream node (as a PLR) creates a backup LSP from itself to a backup egress node in a session different from the primary LSP.

If the LSP is a P2MP LSP and a primary egress node of the LSP is also a transit node (i.e., bud node), the upstream node of the primary egress node (as a PLR) creates a backup LSP from itself to each of the next hops of the primary egress node.

When the PLR detects the failure of the primary egress node, it switches the packets from the primary LSP to the backup LSP to the backup egress node. For the failure of the bud node of a P2MP LSP, the PLR also switches the packets to the backup LSPs to the bud node’s next hops, where the packets are merged into the primary LSP.

5.4.2. Signaling for Facility Protection

Except for backup LSP and downstream label, the behavior of the upstream node of the primary egress node of a primary LSP (as a PLR) follows the PLR behavior for facility backup, which is described in [RFC4090].

For a number of primary P2P LSPs going through the same PLR to the same primary egress node, the primary egress node of these LSPs MAY be protected by one backup LSP from the PLR to the backup egress node designated for protecting the primary egress node.

The PLR selects or creates a backup LSP from itself to the backup egress node. If there is a backup LSP that satisfies the constraints given in the Path message, then this one is selected; otherwise, a new backup LSP to the backup egress node is created.

After getting the backup LSP, the PLR associates the backup LSP with a primary LSP for protecting its primary egress node. The PLR records that the backup LSP is used to protect the primary LSP against its primary egress node failure and MUST include an SERO object in the Path message for the primary LSP. The object MUST contain the backup LSP ID. It indicates that the primary egress node MUST send the backup egress node the service label as a UA label and also send the information about forwarding the traffic to its destination using the label if there is a service carried by the LSP and the primary LSP label as a UA label (if the label is not implicit null). How a UA label is sent is out of scope for this document (refer to [FRAMEWK]).

When the PLR detects the failure of the primary egress node, it redirects the packets from the primary LSP into the backup LSP to the backup egress node and keeps the primary LSP label from the primary egress node in the label stack if the label is not implicit null. The backup egress node delivers the packets to the same destinations as the primary egress node using the backup LSP label as a context label and the labels under as UA labels.

5.4.3. Signaling for S2L Sub-LSP Protection

The S2L sub-LSP protection uses an S2L sub-LSP (refer to [RFC4875]) as a backup LSP to protect a primary egress node of a P2MP LSP. The PLR MUST determine to protect a primary egress node of a P2MP LSP via S2L sub-LSP protection when it receives a Path message with the "S2L sub-LSP backup desired" flag set.

The PLR MUST set up the backup S2L sub-LSP to the backup egress node and create and maintain its state in the same way as if setting up a S2L sub-LSP defined in [RFC4875] from the signaling’s point of view. It computes a path for the backup LSP from itself to the backup egress node, constructs and sends a Path message along the path, and receives and processes a Resv message responding to the Path message.

After receiving the Resv message for the backup LSP, the PLR creates a forwarding entry with an inactive state or flag called "inactive forwarding entry". This inactive forwarding entry is not used to forward any data traffic during normal operations.

When the PLR detects the failure of the primary egress node, it changes the forwarding entry for the backup LSP to "active". Thus, the PLR forwards the traffic to the backup egress through the backup LSP, which sends the traffic to its destination.

5.4.4. PLR Procedures during Local Repair

When the upstream node of a primary egress node of an LSP (as a PLR) detects the failure of the primary egress node, it follows the procedures defined in Section 6.5 of [RFC4090]. It SHOULD notify the ingress node about the failure of the primary egress node in the same way as a PLR notifies the ingress node about the failure of a transit node.

Moreover, the PLR MUST let the upstream part of the primary LSP stay alive after the primary egress node fails by sending the Resv message to its upstream node along the primary LSP. The downstream part of the primary LSP from the PLR to the primary egress node SHOULD be removed. When a bypass LSP from the PLR to a backup egress node protects the primary egress node, the PLR MUST NOT send any Path message for the primary LSP through the bypass LSP to the backup egress node.

In the local revertive mode, the PLR will re-signal each of the primary LSPs that were routed over the restored resource once it detects that the resource is restored. Every primary LSP successfully re-signaled along the restored resource will be switched back.

Note that the procedure for protecting the primary egress node is triggered on the PLR if the primary egress node failure is determined. If link (from PLR to primary egress node) failure and primary egress node alive are determined, then the link protection procedure is triggered on the PLR. How to determine these is out of scope for this document.

6. Application Traffic Considerations

This section focuses on an example with application traffic carried by P2P LSPs.

6.1. A Typical Application

L3VPN is a typical application. Figure 2 below shows a simple VPN that consists of two CEs, CE1 and CE2, connected to two PEs, R1 and L1, respectively. There is a P2P LSP from R1 to L1, which is represented by stars (****). This LSP is called the primary LSP. R1 is the ingress node of the LSP and L1 is the (primary) egress node of

the LSP. R1 sends the VPN traffic received from CE1 through the P2P LSP to L1, which delivers the traffic to CE2. R1 sends the VPN traffic with an LSP label and a VPN label via the LSP. When the traffic reaches the egress node L1 of the LSP, L1 pops the LSP label and uses the VPN label to deliver the traffic to CE2.

In previous solutions based on ingress protection to protect the VPN traffic against failure of the egress node L1 of the LSP, when the egress node fails, the ingress node R1 of the LSP does the reroute (refer to Figure 2). This solution entailed:

1. A multi-hop BFD session between ingress node R1 and egress node L1 of the primary LSP. The BFD session is represented by dots (....).

2. A backup LSP from ingress node R1 to backup egress node La, which is indicated by ampersands (&&&&).

3. La sends R1 a VPN backup label and related information via BGP.

4. R1 has a VRF with two sets of routes for CE2: one set uses the primary LSP and L1 as the next hop; the other uses the backup LSP and La as the next hop.

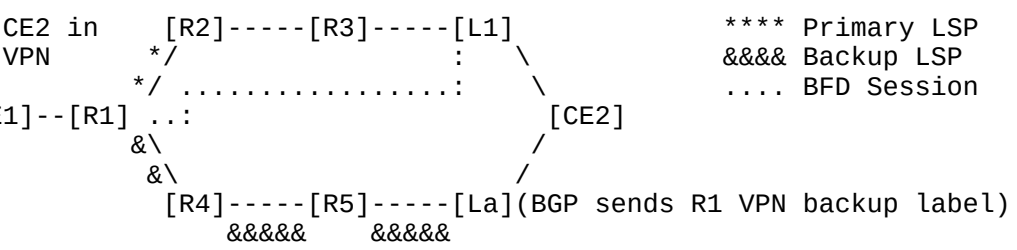


Figure 2: Protect Egress for L3VPN Traffic

In normal operations, R1 sends the VPN traffic from CE1 through the primary LSP with the VPN label received from L1 as the inner label to L1, which delivers the traffic to CE2 using the VPN label.

When R1 detects the failure of L1, R1 sends the traffic from CE1 via the backup LSP with the VPN backup label received from La as the inner label to La, which delivers the traffic to CE2 using the VPN backup label.

The solution defined in this document that uses egress local protection for protecting L3VPN traffic entails (refer to Figure 3):

1. A BFD session between R3 (i.e., upstream node of L1) and egress node L1 of the primary LSP. This is different from the BFD session in Figure 2, which is a multi-hop between ingress node R1 and egress node L1. The PLR R3 is closer to L1 than the ingress node R1. It may detect the failure of the egress node L1 faster and more reliably. Therefore, this solution can provide faster protection for failure of an egress node.

2. A backup LSP from R3 to backup egress node La. This is different from the backup LSP in Figure 2, which is an end-to-end LSP from ingress node R1 to backup egress node La.

3. Primary egress node L1 sends backup egress node La the VPN label as a UA label and also sends related information. The backup egress node La uses the backup LSP label as a context label and creates a forwarding entry using the VPN label in an LFIB for the primary egress node L1.

4. L1 and La are virtualized as one node (or address). R1 has a VRF with one set of routes for CE2, using the primary LSP from R1 to L1 and a virtualized node as the next hop. This can be achieved by configuring the same local address on L1 and La using the address as a destination of the LSP and BGP next hop for the VPN traffic. The cost to L1 is configured to be less than the cost to La.

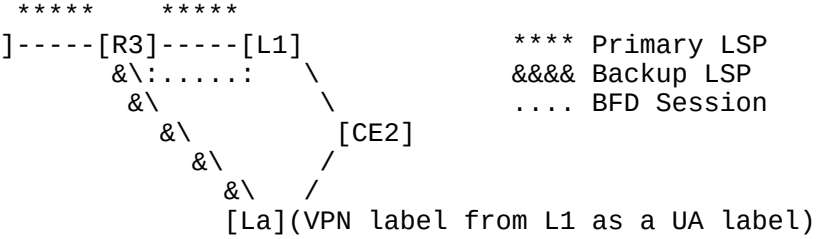


Figure 3: Locally Protect Egress for L3VPN Traffic

In normal operations, R1 sends the VPN traffic from CE1 via the primary LSP with the VPN label as an inner label to L1, which delivers the traffic to CE2 using the VPN label.

When the primary egress node L1 fails, its upstream node R3 detects it and switches the VPN traffic from the primary LSP to the backup LSP to La, which delivers the traffic to CE2 using the backup LSP

label as a context label to get the LFIB for L1 and the VPN label as a UA label to find the forwarding entry in the LFIB to forward the traffic to CE2.

6.2. PLR Procedure for Applications

When the PLR gets a backup LSP from itself to a backup egress node for protecting a primary egress node of a primary LSP, it includes an SERO object in the Path message for the primary LSP. The object contains the ID information of the backup LSP and indicates that the primary egress node sends the backup egress node the application traffic label (e.g., the VPN label) as a UA label when needed.

6.3. Egress Procedures for Applications

When a primary egress node of an LSP sends the ingress node of the LSP a label for an application such as a VPN label, it sends the label (as a UA label) to the backup egress node for protecting the primary egress node. Exactly how the label is sent is out of scope for this document.

When the backup egress node receives a UA label from the primary egress node, it adds a forwarding entry with the label into the LFIB for the primary egress node. When the backup egress node receives a packet from the backup LSP, it uses the top label as a context label to find the LFIB for the primary egress node and uses the inner label to deliver the packet to the same destination as the primary egress node according to the LFIB.

7. Security Considerations

This document builds upon existing work, specifically, the security considerations of [RFC4090], [RFC4875], [RFC3209], and [RFC2205] continue to apply. Additionally, protecting a primary egress node of a P2P LSP carrying service traffic through a backup egress node requires out-of-band communication between the primary egress node and the backup egress node in order for the primary egress node to convey a service label as a UA label and also convey its related forwarding information to the backup egress node. It is important to confirm that the identifiers used to identify the primary and backup egress nodes in the LSP are verified to match with the identifiers used in the out-of-band protocol (such as BGP).

8. IANA Considerations

IANA maintains a registry called "Class Names, Class Numbers, and Class Types" under "Resource Reservation Protocol (RSVP) Parameters". IANA has assigned a new C-Type under the PROTECTION object class, Class Number 37:

Value	Description	Definition
3	Egress Protection	Section 4.1

IANA has created and now maintains a registry under the PROTECTION object class (Class Number 37) and Egress Protection (C-Type 3). Initial values for the registry are given below. Future assignments are to be made through IETF Review [RFC8216].

Value	Description	Definition
0	Reserved	
1	IPv4_PRIMARY_EGRESS	Section 4.1.1
2	IPv6_PRIMARY_EGRESS	Section 4.1.1
3	IPv4_P2P_LSP_ID	Section 4.1.2
4	IPv6_P2P_LSP_ID	Section 4.1.2
5-127	Unassigned	
128-255	Reserved	

9. References

9.1. Normative References

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